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PLANETARY OBSERVING*

BY F. M. BATESON

OBSERVATION of the principal planets has always attracted the amateur. His attention has been devoted mainly to Mars, Jupiter and Saturn, but Venus too is within range of some amateur's telescopes.

In making observations of the planets there are certain fundamental points, which however commonplace they may appear, bear repeating. They can be summarized as:

1. Keep a clear record of any observation, preferably in a suitable exercise book.
2. Drawings should be made on separate sheets of smooth drawing paper or on suitable cards.
3. Do not pile observations in the notebook but communicate them to an organisation where they can be used in conjunction with other records.
4. Commence each record by stating the date; time (in U.T.); place and instrument, with powers employed. Do not forget to include the year. It may sound hardly credible but at times the writer has received records such as "Tuesday Jupiter" followed by the observation.
5. State briefly weather conditions at commencement and during observations. If the seeing is given on the usual scale of 0 (hopeless) to 10 (perfect) it is of material assistance. Nobody wants an essay on the weather and two brief lines stating amount of cloud, haze or other obscuration, seeing, and any other relevant information are all that are necessary.
6. Each drawing should have alongside the date with year; U.T.; seeing and observer's name with instrument and power used. Where applicable, such as with Jupiter, longitude of central meridian or other such data is also stated.
7. Have as few pre-conceived ideas as possible. *Observe and draw just what you see not what you thought you should see.*
8. Drawings should be made in a short time due to the rotation of the planets. Sketch in rapidly and accurately the principal features first, taking care to have them in their correct position; then add the fainter details commencing at the

*Reprinted from *Southern Stars*, September 1954.

preceding limb. ***Complete the drawings at the telescope. Never alter drawings afterwards.***

9. Accuracy in drawings is much preferred to artistic work. Few observers are artists; most can be accurate.
10. Use pencils for drawing; shading with a stump if necessary. Coloured drawings are all right for the artist who knows what he is doing, but most of us lack the necessary ability.
11. Do not expose the eyes to a bright light whilst observing. For illuminating the notebook, etc., use a well shaded light, preferably one with a red globe, or covered with red paper.
12. With all the planets regular observations bring skill from the practice acquired.
13. Do not think that in these days of large telescopes and modern techniques there is no work for the amateur. Our knowledge of the surface features of the planets has come largely from the regular observations by amateurs. An instance is the *B.A.A. Jupiter Memoirs,* within which lies almost all our knowledge of the surface features of this planet.

Before dealing with the maïn planets individually it is useful to consider where the amateur can obtain more extended hints on planetary observing. Much can be gleaned from current periodicals and from books, but the best modern publication is known as the B.A.A. Green Book. This is entitled *The British Astronomical Association; its Nature, Aims and Methods,* 1952 Edition. The notes for amateurs in *Sky and Telescope* are good. *The Strolling Astronomer,* published monthly by the American Association of Lunar & Planetary Observers contains much sound advice. *The Nautical Almanac* and *B.A.A. Handbook* are essential to the serious observer.

Venus

Due to the faint and indefinite nature of its markings, this planet is apt to be disappointing. It is best observed in daylight or twilight when the glare is not too strong.

The perfection of the object glass, or mirror, is more essential in observing Venus than the size of the telescope. Good work has been done with a 5-inch refractor. Eyepieces should be chosen with care and wide field ones are the best.

Observations broadly consist of:

(a) Recording notes of the appearance of surface markings;
(b) Drawings;
(c) Determination of the exact date of dichotomy;
(d) Observations of the unilluminated part of Venus, and
(e) Appearance of the terminator.

Drawings can be made on the scale of two millimetres per second of arc. Most markings, which are not genuine surface features, are indefinite

and should be shown as such. Indeed, depicting this planet largely consists of illustrating the play of light and shade, rather than sketching sharply defined markings.

At times bright, even brilliant, white areas are seen especially around the cusps. These areas are best marked off on the drawings by dotted lines.

The writer marks on his drawings letters—A; B; C; etc.—as references. Such letters should be shown alongside the drawing not on it. The descriptive notes then refer to these letters, thus making the identification certain. Such descriptions can be brief and, unless one is using a reflector, completely free from reference to colour.

Dichotomy is the term used when the terminator is straight. Determination of the exact date of this occurrence is important. The terminator varies considerably in shape and often the cusps appear to extend beyond the terminator. When this phenomenon is seen it should be noted, whilst the shape of the terminator should always be stated or shown on a drawing.

On occasions the unilluminated portion of Venus has been seen much like the old Moon in the new Moon's arms. But the appearance varies considerably and full details should be recorded of any such occurrence.

Mars

This article will not tell you how to see the canals in one easy lesson. More nonsense has been written on this planet than on all the rest of the heavens. In observing Mars it is essential to disregard all previous records as far as is possible. *Don't consult reference books showing previous drawings until an opposition is over.*

At favourable oppositions Mars is a fascinating study and many of the surface features are easy to see. Instruments of 3 inches and upwards will provide glimpses of the surface features. However for useful work a refractor of 6 inches or larger and a reflector of 8 inches or more are required.

The principal observations concern:

(a) Drawings of the planet, i.e., whole disk drawings.
(b) Notes on the features visible.
(c) Transits.
(d) Records of clouds; changes in colour; temporary obscurations.

Drawings should be made on smooth paper, or cards of Bristol Board, cut to a uniform size, say 6 inches by 4 inches. The actual drawings were formerly asked for by the B.A.A. on a scale of 2 inches to the planet's

diameter. Now they recommend a scale of 3 millimetres = 1 second. Black and white sketches are best unless the observer is a real artist. All drawings should be completed at the telescope and never retouched afterwards.

Draw exactly what you see. If an object is doubtful omit it, although it can be mentioned in the notes. Draw the polar cap first, taking care to get its correct size and position. Then add the more prominent features; finally add the fainter detail. The longitude of the central meridian and latitude of the centre of the disk should be stated on all drawings.

Any descriptive notes should be clear and concise, leaving no doubt as to which object is referred to. The colour of the disk, as well of the various regions, should be stated. The writer uses letters on his drawings to identify the objects described, leaving the identification of names until an opposition finishes. This cuts to a minimum any tendency to bias after inspection of charts or drawings by others.

Reliable determinations can be made of transits of well defined markings across the central meridian of the disk only close to the actual opposition date. These are then useful.

At times clouds, or veiling of the surface, have been noted. It is essential that an accurate record be kept of such events. Changes in colour should be noted, as well as changes in intensity. These include any brightening of features near the limb.

Jupiter.

Useful work has been done with a 3-inch refractor, but a somewhat larger instrument is necessary. At the same time, Jupiter is the most interesting planet to study and one that can be followed for several months each year even with a moderate aperture. It presents a most diversified and constantly changing aspect.

Any intending observer should first learn the names of the various belts (dark regions) and zones (bright spaces between the belts). These can be ascertained from the diagrams in the B.A.A. Memoirs, most reference books or from the B.A.A. Green Book.

The work of the Jupiter Section consists mainly of:

(a) Timing transits of markings across the central meridian.
(b) Drawings with descriptive notes.
(c) Measurement of relative intensities of markings.
(d) Satellite observations.

Transit observations are the most important, since they enable the rotation periods for the various currents to be determined. The central

meridian is an imaginary line joining the north and south poles of the planet. Transit recording consists of noting the time, to the nearest minute, when an object is on the central meridian.

Observers should refer to the B.A.A. Green Book mentioned earlier, where an excellent illustration is given of this type of record. It should be noted, however, that each observer should number his transit observations from 1 upwards for each opposition. Thus, if the last transit on say 1954, April 1st was 145; the first observation of 1954, April 2nd, or whatever was the next date of observing, would be 146. For the following opposition start again at 1. See that sufficient detail is stated to identify the object clearly and again an inspection of the B.A.A. Green Book will make this clear.

Drawings must be on a scale that allows for the equatorial bulge. Draw an ellipse to represent the planet's disk with the diameter of the major axis, 2½ inches. The ratio of the polar to the equatorial diameter should be 15 to 16. But, the writer can supply blank forms for drawings to any intended observer.

Drawings should be in black and white. The most obvious features should be sketched in quickly and accurately. The details are then added, working from the preceding limb. Due to the rapid rotation of Jupiter a drawing must not take too long, or else the aspect alters. All whole disk drawings should show the longitudes of the central meridian according to both Systems I and II at the time of observation.

Descriptive notes can be brief, provided details of transits have been recorded. Often transit observations and notes are best supplemented by strip drawings, i.e., sketches of small portions of the disk showing the regions of greatest activity amongst which the majority of the transits have been recorded. On such sketches the serial numbers from the transit observations can be indicated so that identification of the objects concerned is certain.

Colour records are best when a reflector is used. In referring to colours endeavour to avoid such terms as "warm Indian red." Such terms have no meaning except in the imagination of the observer concerned. Stick to colour descriptions that are less fanciful, but which do convey a definite idea of the appearance noted.

The relative intensities of the belts and zones are best confined to noting the order of darkness for the belts and of brightness for the zones. The darkest belt is placed first; and the brightest zone first.

The four principal satellites can be usefully observed. The various transits, occultations and eclipses can be timed. In particular the appearance of both the satellites and their shadows during transit should be

noted. At certain times the satellites undergo mutual eclipses, etc., which should always be recorded. Predictions of such phenomena appear in the *B.A.A. Handbook* for the years in which these are visible.

Saturn.

For this planet, telescopes larger than those suitable for Jupiter are generally necessary.

The greatest difficulty experienced by the average amateur is in getting the scale of his drawings of the globe and rings correct. Any observer should consult the *B.A.A. Journal,* Vol. 63, No. 8, 1953, October. There, Mr. Heath gives some useful hints on getting accurate outlines of the rings and globe with a minimum of effort.

Unlike Jupiter, whole disk drawings of Saturn are preferred. These should be made when possible. When a spot, white or dark, is visible detailed drawings of it, if prominent, should be made. Apart from drawings the principal work that can be done on Saturn is:

(a) Transits of markings across the central meridian.
(b) Description of any unusual spot or patch on globe or rings.
(c) Noting changes in shape or position of belts.
(d) Recording the aspect presented by the shadow of globe on rings and shadow of rings on globe, especially watching for any irregularities.
(e) Estimates of relative intensities of rings, belts and zones.
(f) If telescope is of sufficient size, determination of the magnitude of the satellites.

Transit of markings across the central meridian should be recorded as for Jupiter. As transits of spots are uncommon, reports of such objects, should be sent immediately to the Carter Observatory so that other observers can be notified. Most members can no doubt remember instances of past spots being detected.

Should the position or shape of the few belts visible change it should be noted. So should any irregularities in the shadows caused by the globe on the rings, or by the rings on the globe.

In estimating the relative intensities of the rings, belts and zones a scale of 0 (brightest) to 10 (darkest) is used and halves and quarters are also used. Two standards are adopted, viz., 1 for the brightness of the outer ring B in the ansae adjoining Cassini's Division and 10 for the blackness of a very dark sky or deep black shadow. Observers should consult the instructions in the B.A.A. Green Book.

Estimates of the magnitude of the satellites are made as for variable star observations, assuming the magnitude of Titan as 8.3. The greatest care must be exercised to see that the satellites are correctly identified.

For this purpose the *Nautical Almanac* is essential. Some of the satellites undoubtedly change in brightness. Again the B.A.A. Green Book contains more detailed instructions.

General.

The foregoing contains a brief outline of some of the principal features to be watched and recorded for these planets. It is far from exhaustive. No mention has been made for instance of occultations of stars by the planets; of micrometer measures of the positions of belts and much other information that can be observed.

When the observer has recorded observations he naturally wishes to know what to do with them. Jupiter observations should be sent to the writer; or if the observer prefers direct to the Director of the B.A.A. Jupiter Section with a copy to the writer.

The B.A.A. Section Directors always welcome records from observers of Venus, Mars and Saturn whether the observer is a member of the B.A.A. or not. Or the observer may prefer to send his records to the American Association of Lunar and Planetary Observers. Or again he can send any observations to the writer, who is always prepared to see that they are sent on to those able to make use of them. But whatever happens don't make a useful series of observations and then be too lazy to communicate them to some person able to turn them to good account.

THE EVOLUTION OF STARS

By J. B. Oke

I. Introduction

During the last few years advances in various fields of astronomy have made it possible to get some idea of the ways in which stars change as they grow old. The most important theoretical work has been the construction of stellar models in which the chemical composition is not uniform throughout the star; the most important observational results have been the determinations of accurate spectrum-luminosity and colour-magnitude diagrams for galactic and globular star clusters. (For a discussion of spectrum-luminosity or Hertzsprung-Russell diagrams the reader is referred to an article by K. O. Wright, *R.A.S.C., Jour.*, vol. 44, p. 17, 1950. The most general appearance of the diagram is shown in figure 1 which is taken from this paper.) It is the purpose of this article to review these and other recent theoretical and observational advances and to discuss what can be inferred about the evolution of stars which are not too different from the sun.

II. Main-sequence Stars

Nearly all the theoretical problems involved in the study of the evolution of stars are connected with the structure of the stars far inside the surface. Although this region of a star is not observable, astrophysicists have found it possible to predict the conditions within a star of a given mass using only the laws of physics together with an assumption about the chemical composition, that is, the relative amounts of hydrogen, helium, and heavier elements in the star. When the astrophysicist has completed his predictions about the way in which the temperature and pressure vary with depth inside the star he has constructed a "model". To test his theoretical work he must now see how nearly his model star resembles real stars of the same mass in respect to quantities which can be observed, namely intrinsic luminosity and radius. If his model is a good one, then by choosing the chemical composition properly his model star will have the same luminosity and radius as real stars of the same mass.

The early theoretical model stars were constructed on the basic assumption that the stars had the same relative amounts of hydrogen, helium, and heavier elements at all points in the star. In other words the stars were assumed to be homogeneous. The model stars so constructed

were found to be very much like real main-sequence stars. These models have the following characteristics. (1) The chemical composition is uniform throughout the star. (2) The percentages by weight of hydrogen, helium, and heavier elements are about 70, 29, and 1 respectively. (3) The innermost 10 per cent. of the radius which also contains about 10 per cent. of the mass of the star, is in a violent state of agitation. This agitated

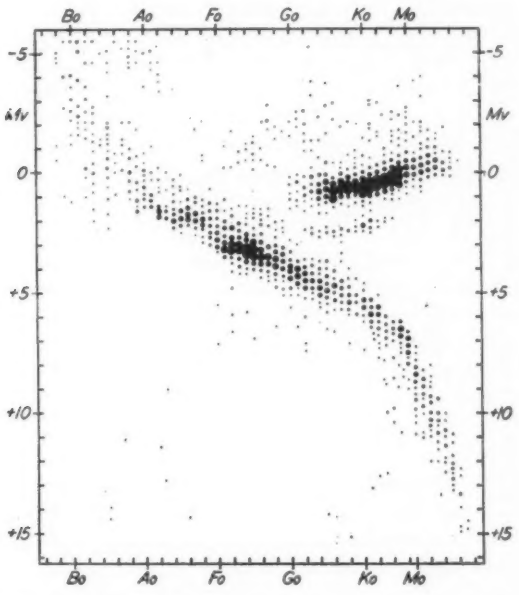

FIG. 1—The Hertzsprung-Russell diagram for a large number of stars whose distances are known. The stars sprinkled diagonally from the upper-left to the lower-right corner of the diagram are known as main-sequence stars. The stars concentrated in the upper right-hand corner, at $M_v = 0$, are the red-giant stars; those scattered in the lower left-hand side of the diagram are the white-dwarf stars. (From a paper by K. O. Wright.)

region is called the *convective core*. In the remaining outside portion of the star the material is not agitated and this outer region is called the *radiative envelope*. (4) For stars somewhat brighter than the sun the energy which keeps the star shining is produced by a nuclear chain reaction, called the carbon cycle, which converts hydrogen into helium and at the same time releases vast quantities of energy. This particular

chain reaction occurs only at the high temperatures which are attained in the central 10 per cent. of the radius of the star. (5) For stars as faint as or fainter than the sun the energy is produced by another chain reaction, the proton-proton reaction, which also converts hydrogen into helium; the energy production is confined to the inner 30 per cent. of the radius of the star.

The above models can be interpreted immediately in terms of stellar evolution. Since it is believed by many astronomers that stars condense from clouds of interstellar gas and dust, one would expect newly-formed stars to be chemically homogeneous. If this is the case, then the models just described should be appropriate and, as mentioned above, such models represent main-sequence stars. One therefore can conclude that some main-sequence stars are young stars, young in the sense that they have not had time to change appreciably since they were born.

III. The Evolution of Red-Giant Stars

When an attempt was made to apply the homogeneous models to red-giant stars the difficulty arose that the central temperatures of the stars had to be so low that no nuclear processes could occur. Consequently it was impossible to account for the high luminosities of these stars. Öpik, however, demonstrated[1] that one way out of the dilemma was to to have the chemical composition change far down in the star, for instance by making the deep interior mostly of helium and the outer layers mostly of hydrogen.

Before we investigate such a model it is necessary to see whether such conditions are likely to occur in stars. Both the carbon cycle and the proton-proton reaction will set up the necessary chemical composition difference since they convert hydrogen to helium only in the central region of the star. But such a composition change will be destroyed if there is much mixing between the centre and outside of such a star. Is it possible to determine whether a star is mixed or not? There are three pieces of information which suggest that stars like the sun do not mix appreciably. (1) The ratio of the abundance of nitrogen to that of carbon for material which has been in the deep interior of stars should be about 30 if the best determined rates for the various nuclear processes are correct. At the surface of the sun the observed ratio[2] is 2 which indicates that this material was never in the deep interior. (2) By the same reasoning the ratio of the abundances of two isotopes of carbon, that of mass 12 to that of mass 13, should be 5 in material which has been deep in the interior. At the surface of the sun[3] the ratio is at least 30, again suggesting no mixing. (3) It can be shown that all the lithium in the deep interior

of the sun should have been used up in nuclear reactions. Yet lithium is observed at the surface.[4] Thus the available evidence suggests that mixing does not occur in stars like the sun and hence inhomogeneities such as are required to explain the red-giant stars should occur.

But are there stars old enough so that inhomogeneities could have been produced? It can be shown readily that the sun, shining at its present intensity, will use up all the hydrogen in the innermost 10 per cent. of its mass in about 10^{10} years. Sirius, a much brighter star does the equivalent in only 10^{8} years. If these times are compared with the age of the earth, about 4×10^{9} years, then it is clear that there should be many stars which have become inhomogeneous.

Assuming that inhomogeneities in the chemical composition do occur in stars, it is possible to calculate how a homogeneous main-sequence star should change as it gradually uses up its supply of hydrogen in the deep interior. The first steps in tracing the evolution of a star, originally homogeneous, were made by Schönberg and Chandrasekhar.[5] They showed that as the core of the star is converted from hydrogen to helium the star gradually becomes brighter and bigger. When all the hydrogen from the core disappears the core can no longer produce energy. The energy is produced instead in a thin shell surrounding the core. This shell keeps the core at a constant temperature and the core is then said

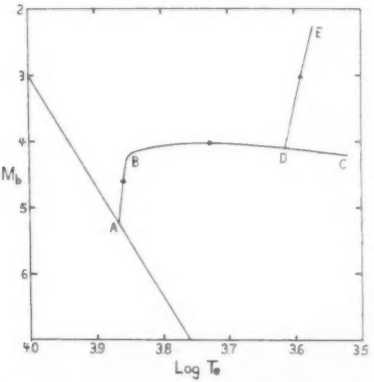

FIG. 2—The theoretical evolutionary track in the Hertzsprung-Russell diagram of a star according to the evolutionary models of Sandage and Schwarzschild is shown by the curve *ABDE*. The main sequence is indicated by the straight line passing through *A*. The diagram is plotted in terms of absolute bolometric magnitude and the logarithm of the effective temperature of the star. These quantities can be related directly to those plotted in figure 1.

to be *isothermal*. As the hydrogen is used up farther and farther out from the centre of the star the core includes more and more of the mass of the star until about 12 per cent. of the total mass is contained in the isothermal core. The star at this stage is one magnitude brighter and 1.7 times larger than originally but it still has the same surface temperature. This part of the evolution of the star is shown by the segment of the curve from *A* to *B* in figure 2. The point *A* represents the original position of the star in the Hertzsprung-Russell diagram when it was homogeneous and on the main sequence. Figure 2 is plotted in terms of absolute bolometric magnitude, M_b, which is related to the intrinsic luminosity of the star, and logarithm of the effective temperature, $\log T_e$, of the star which is related to the spectral type.

The evolutionary history of a star after it reaches point *B* has been traced theoretically by Sandage and Schwarzschild.[6] They suggested that at the point *B* the isothermal core probably starts to contract releasing gravitational energy and at the same time heating up. They further showed that as this happens the star as a whole becomes much larger and cooler very rapidly. The detailed behaviour of the star is shown in figure 2 by the path from *B* to *C*. It was also suggested by Sandage and Schwarzchild that before the star reaches *C* its central temperature may be sufficiently high so that helium can be converted into carbon by a nuclear reaction,[7] thus supplying a new source of energy. If this happens, then the star instead of going all the way to *C* will at some stage *D* suddenly become brighter and go towards *E*.

At the present time the theoretical work on the evolution of stars has not gone beyond this point. In fact, even the evolutionary tracks just described are very uncertain beyond the point *B*. Other inhomogeneous models have been proposed which differ in certain details from those described here, but, very roughly, all models suggest that the star moves off the main sequence to the giant-star region. The evolutionary track described here is probably the best theoretical one available at the present time.

IV. Observational Evidence for the Evolution of Stars

It is, of course, impossible to observe the evolutionary changes in a single star because of the long times involved. But there is another way to observe such changes which is almost as good. Stars of large mass and brightness evolve from the main sequence much more rapidly than less massive and fainter stars. If it is assumed that all stars in a certain group originated on the main sequence at the same time, and if it is also assumed that all the stars evolve in a similar way, then it is possible to

predict the Hertzsprung-Russell diagram for the group of stars using the evolutionary tracks discussed in section III. Such diagrams are shown in figure 3b for groups of stars of particular ages. As in figure 2 the absolute bolometric magnitude is plotted against the logarithm of the effective temperature. It should be stressed that these curves are not

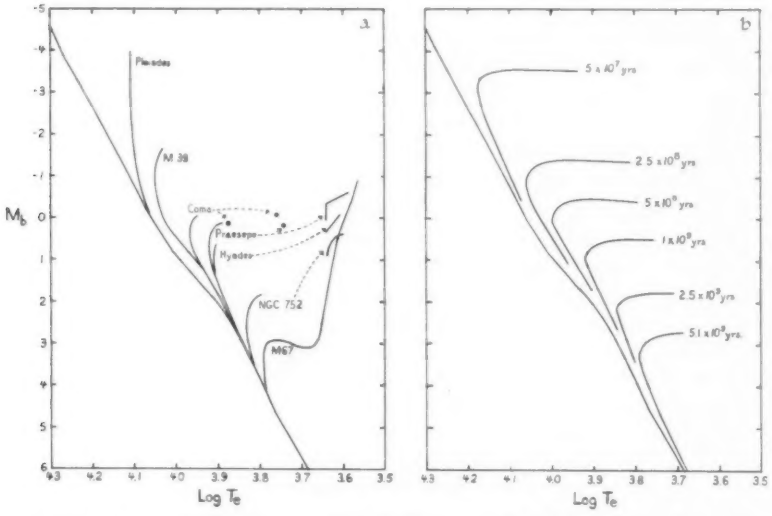

FIG. 3a—Schematic Hertzsprung-Russell diagrams plotted in terms of absolute bolometric magnitudes and logarithms of effective temperatures for a number of galactic clusters. It is assumed that the faintest stars in each cluster fall on the main sequence which is indicated by the curve farthest to the left.

FIG. 3b—The theoretical evolutionary models of Sandage and Schwarzschild have been used to predict the theoretical Hertzsprung-Russell diagrams for clusters whose ages are shown in the figure. It is assumed that the stars originated on the main sequence shown by the curve farthest to the left. The theory predicts a scarcity of stars beyond the sharp turn-off point of each curve.

evolutionary tracks of individual stars but rather the expected positions in the Hertzsprung-Russell diagram of a group of stars of different masses, originally sprinkled along the main sequence shown in the figure, after a certain period of time has elapsed. Since the stars move to the right very rapidly after passing point *B* (figure 2), similarly, in figure 3b the numbers of stars will drop nearly to zero just beyond the sharp turn-off point.

There are many systems of stars in which the member stars are probably of the same age. These are the galactic and globular clusters. If the theory is correct the Hertzsprung-Russell diagrams for such clusters will look like those in figure 3b. In figure 3a are shown the observed schematic diagrams for the galactic clusters: the Pleiades,[8] M 39[9] Coma Berenices,[10] Praesepe,[11] the Hyades,[12] NGC 752[13] and M 67.[14] The original diagrams, plotted in terms of visual magnitudes and colours, have been reduced to bolometric magnitudes and log T_e scales. The position of the curve for NGC 752 is rather uncertain. It can be seen that for M 39, Coma Berenices, Praesepe, the Hyades, and NGC 752 the observed and computed Hertzsprung-Russell diagrams are very similar in shape and the numbers of stars do drop off rapidly just beyond the sharp turn-off point just as predicted by theory. Actually two stars in Coma Berenices and one in Praesepe are the only ones found in the *B* to *D* region (figure 2) where the stars move so quickly. This is also the region to the left of the giant branch in figure 1 which is almost devoid of stars; it is called the Hertzsprung gap. A number of stars are found on the extreme right of the diagram, in the giant branch, for the Hyades, Praesepe, and NGC 752. These stars may represent the points where the conversion of helium into carbon occurs. But it must be admitted that it could indicate something very different which is still unknown.

The Pleiades diagram does not agree very well with the theory. But there may be other phenomena involved in the Pleiades stars which are of early type and which rotate.[15] For instance, since it is possible that the rapid rotation of the stars causes some mixing then the models discussed in section III may not apply at all. For the cluster M 67, the oldest cluster shown, the Hertzsprung-Russell diagram agrees fairly well with the theoretical curves near the main sequence, but does not show the large drop in numbers of stars at the first turn-off point; instead the numbers of stars run smoothly along the whole schematic diagram shown. The absence of the Hertzsprung gap which is so obvious in other clusters and which is predicted by the theory, probably means that the theory is not entirely adequate for stars as faint as those in M 67. Another very old globular cluster, M 3, displays a Hertzsprung-Russell diagram,[16] shown in figure 4, very similar to that of M 67.

When the Hertzsprung-Russell diagram is plotted in terms of bolometric magnitudes and logarithms of effective temperatures, there is one feature which is not apparent when visual magnitudes and colours of stars are plotted. This is the very sharp rise in the bolometric magnitude of the giant branch for log T_e less than 3.6. This corresponds to the redder and cooler stars in the giant branch. The plots shown in figure 3a

suggest the possibility that the curve for M 67 indicates roughly the reddest and coolest stars to be found at any given absolute magnitude. It is possible that brighter stars, such as the brighter stars in Praesepe, move to the right until they approach this limit and then slow down and move almost vertically upwards in the diagram. This vertical motion is not suggested at all in the Hertzsprung-Russell diagram which plots visual magnitudes and colours.

One can sum up the results of the comparison of the theoretical and observational Hertzsprung-Russell diagrams for clusters in general by saying that the theory seems to be proceeding in the right direction. The results for the Pleiades and M 67 on the other hand, indicate that there is still much to be learned about the theory of the evolution of stars.

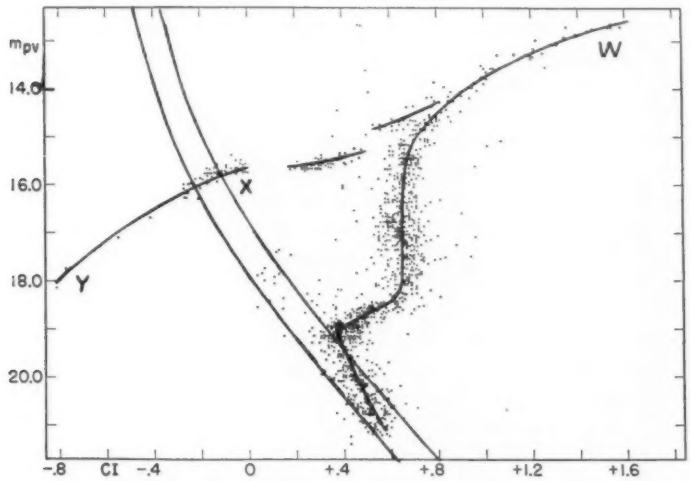

FIG. 4—The colour-magnitude diagram for M 3 adapted from that published by Sandage. The plotted quantities are related directly to those used in figures 2 and 3. (See figure 5 also.) The double curve represents the main sequence.

V. THE LIFE HISTORIES OF STARS

Although it is still impossible to follow very much of the total evolution of a star from a theoretical point of view, it is possible to interpret the Hertzsprung-Russell diagrams for the star-rich globular clusters as an evolutionary process for stars slightly brighter than the sun. The method is essentially the reverse of that used in section IV; the evolutionary

tracks for individual stars are obtained from the observed Hertzsprung-Russell diagram. The method has been applied by Sandage[17] to the Hertzsprung-Russell diagram for M 3, a representative globular cluster. The assumption is made that the stars evolve according to the theory only from point *A* to point *B* (figure 2). It is also assumed that the frequency of stars when they were on the main sequence changed smoothly with the absolute magnitude, and that stars of slightly different masses evolve in a similar way. The resulting evolutionary tracks are shown in figure 5 which is taken from Sandage's paper. These tracks indicate that a star begins on the main sequence, rises about one magnitude, then becomes much larger and cooler until it reaches the top of

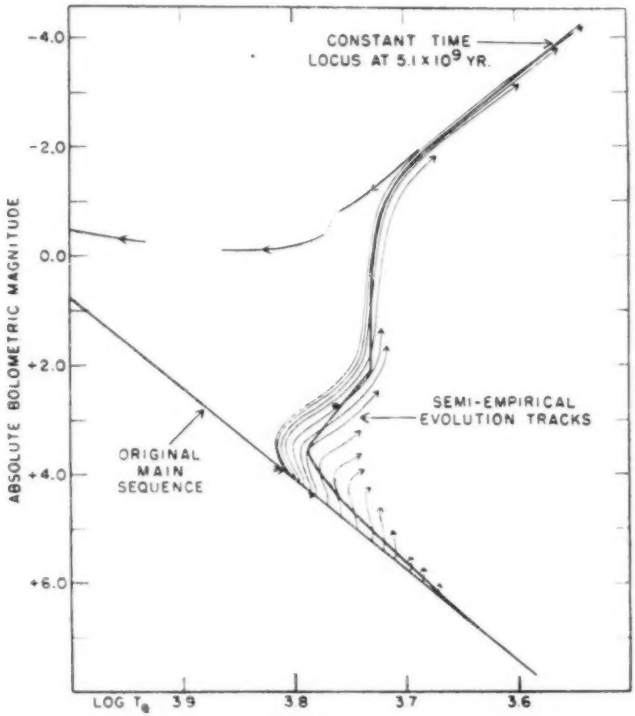

FIG. 5—The heavy solid curves represent schematically the main sequence and the Hertzsprung-Russell diagram for M 3 shown in figure 4. The thin curves are the semi-empirical evolutionary tracks for individual stars. (From a paper by Sandage).

the diagram at absolute bolometric magnitude —4.0. Sandage has demonstrated that at this point in its history the star will have used up most of its entire supply of hydrogen. The star then begins to collapse and one surmises that the star moves to the left across the horizontal branch near bolometric magnitude 0 towards the main sequence. From figure 4 it appears that the star crosses the main sequence near *X* and becomes very hot and small by the time it reaches *Y*. It should now be nearly devoid of hydrogen.

It is possible only to speculate about the remaining history of the stars. It is clear that one should be guided in this by considering only objects which are known to be deficient in hydrogen. An important group of such stars are the white-dwarf stars: tiny, hot stars far below the main sequence. It has been shown that they can have no hydrogen in their interiors.[18] It appears plausible, therefore, that the stars near *Y* in figure 4 finally collapse into white dwarfs. It has been shown by Chandrasekhar[19] that white dwarfs cannot have masses greater than 1.5 solar masses. If a star like the sun evolves as described in previous paragraphs to the region *Y* (figure 4) then there is apparently nothing to prevent it from becoming a white dwarf. On the other hand, a star more massive than 1.5 solar masses can probably reach region *Y* without difficulty but it cannot become a white dwarf without losing mass. There is a clue which suggests that stars may indeed lose mass at this stage. A study of the Crab Nebula by Minkowski[20] showed it to be very deficient in hydrogen. It is believed that the nebula is the remnant of a supernova explosion seen by the Chinese in 1054 A.D. The available evidence also suggests that stars after they have become supernovae or novae, settle down as stars in regions near *Y* in the Hertzsprung-Russell diagram. It is tempting to think that supernovae, and perhaps novae are massive stars losing weight while collapsing into white dwarfs. In summary, there is some evidence to suggest that stars after reaching a stage of evolution which locates them in the region *Y* of the Hertzsprung-Russell diagram, will collapse into white dwarf stars perhaps shedding matter as they do so.

V. Conclusions

The evolutionary history outlined in the last section has been inferred using stars which originated on the main sequence about a magnitude brighter than the sun. Such stars are of the type found in globular clusters and in the galactic cluster M 67. These stars begin on the main sequence, gradually brighten by about one magnitude, then increase in size and become cooler, reaching perhaps twenty times their original

size. They then collapse, cross the main sequence, become very hot, small stars, and finally may collapse into white dwarfs. It is possible that stars like the sun, as they grow old, will have a similar evolutionary history.

The evolutionary history of more massive stars which were originally of spectral type A is not nearly so clear. The evidence from clusters like Praesepe and the Hyades suggests that such stars rise about one magnitude then move very rapidly to the right in the Hertzsprung-Russell diagram. When the stars have become 8 to 10 times larger than they were originally, some mechanism, perhaps the conversion of helium into carbon, drastically reduces the rate at which the stars expand. The stars then appear to become slowly brighter. Unfortunately there are no known systems of stars which are sufficiently populous to show the remaining history of such stars. One can only guess that beyond this stage they behave in much the same way as stars in globular clusters. In order to find out more about the evolution of these more massive stars it will probably be necessary to study many more galactic clusters, particularly those which are old and rich in stars.

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THE EFFECTIVE QUANTUM EFFICIENCY IN ASTRONOMICAL SPECTROSCOPY*

By P. E. Argyle

ABSTRACT

An estimate of the effective quantum efficiency of fast emulsions used in astronomical spectroscopy is made by comparing the actual performance of the Kodak 103aO emulsion with the calculated performance of an "ideal" emulsion, whose performance is limited only by the signal-to-noise ratio in the starlight itself. It is found that the ideal emulsion would be seven magnitudes faster than the 103aO. An electronic method of obtaining spectra that shows promise of greater efficiency than photographic methods, at least in certain wave-length regions, is briefly described and some preliminary experimental results are mentioned.

The only primary recording medium widely used in astronomical spectroscopy is the photographic plate. Among the many advantages associated with the photographic plate, and chiefly responsible for its use, are simplicity, cheapness, small physical size, and the fact that the record obtained on it is "three-dimensional". This latter feature allows a wide range of wave-lengths and intensities to be recorded simultaneously, and permits the inclusion of comparison and calibration spectra. Unfortunately, high efficiency is not one of the properties of the photographic plate, and the only device possessing higher efficiency in the visible region, the photoelectric cell, is one-dimensional. Thus the usefulness of the astronomical spectrograph is at present more drastically limited by the low efficiency of the photographic plate than by any other factor. The calculations made here show that this well-known limitation is possibly of the order of seven stellar magnitudes, and the main purpose of this paper is to suggest means of avoiding a part of this large loss of efficiency.

Various authors[1] have measured the quantum efficiency† of the photographic plate, but the data they have obtained are not easily used to predict the visibility of spectral features on a spectrogram. There are two chief reasons for this fact: (1) the measurements of quantum efficiency are often made on special emulsions whose characteristics are but remotely similar to those used in astronomical spectroscopy, and (2) the visibility of spectral features depends strongly on other factors in addition

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†The quantum efficiency of an emulsion is defined as the reciprocal of the average number of photons in the effective wave-length region required to produce one developable grain.

to quantum efficiency. These include contrast, background density, and degree of uniformity of the developed emulsion. Therefore it seems of interest to make a comparison between the actual performance of an astronomical spectrograph using a typical fast emulsion and the calculated performance of the same spectrograph using an ideal emulsion.

We may define an ideal emulsion as one which produces, for each impinging photon having a wave-length in the region under study, one perceptible grain at the site of the impact, and no other grains. For practical reasons, the grains should be small enough so that the inevitable overlapping which must occur in dense portions of an image is insufficient to prevent accurate grain counting. Quantitative study of a spectrum on such an emulsion would then be done from a plot of grain count versus wave-length.

In order to compare the performance of this ideal emulsion with that of currently used emulsions it is necessary to set up a criterion which is applicable to both. One such criterion is the signal-to-noise ratio as commonly used in communication theory. One could compute (for a given frequency response) the S/N ratio which would appear in a record of grain count versus wave-length for the ideal emulsion, and compare this number with the same ratio for a real emulsion analyzed by means of an intensitometer having the same frequency response. Attractive as the use of this standard statistical concept might be, it is probably less simple than the use of the standard deviation, which is very easy to obtain for both recording media.

The standard deviation of intensity for a real emulsion can be obtained with sufficient accuracy by selecting a number of ordinates from the intensitometer record of a uniformly exposed region in the emulsion and forming the root-mean-square value of their deviation from the mean for the region. A portion of a typical intensitometer record is reproduced in figure 1. The abscissa for each ordinate selected must be separated from adjacent ones by an amount equal to or greater than the width of the analyzing intensitometer slit in order that the samples of intensity so obtained may be independent. These samples will provide randomly distributed values of intensity if they are selected without regard to the ordinates, and the simplest way of doing this is to take abscissae which increase uniformly by an amount at least as great as the slit-width.

The standard deviation for a uniformly exposed region in the hypothetical emulsion is merely $\sqrt{n}$ where n is the mean number of grains per slit-width in the region. This value arises from the fact that the distribution of grain density obeys Poisson statistics.*

*In a real emulsion, however, grain density obeys neither Poisson nor Gaussian statistics. See L. A. Jones and G. C. Higgins, *J. Opt. S. Am.*, vol. 36, p. 203, 1946.

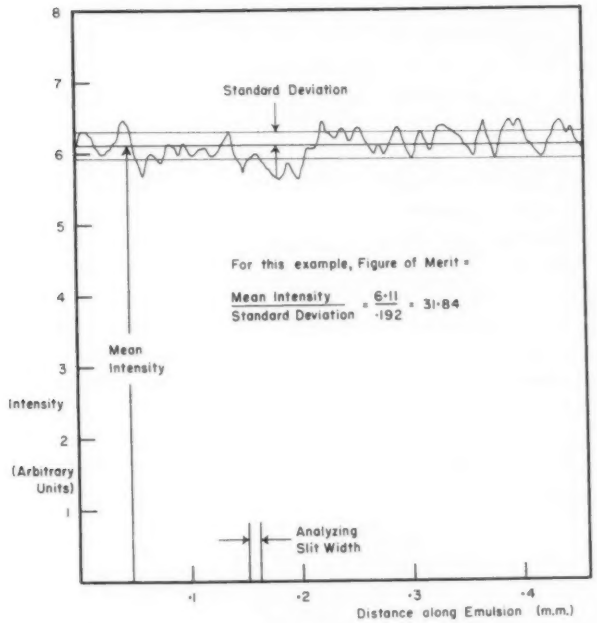

FIG. 1—A portion of a typical intensitometer record.

By forming the quotient of mean intensity divided by standard deviation for a given slit-width we obtain a number analogous to the signal-to-noise ratio which can serve as a figure of merit for the real emulsion. This figure of merit can then be compared with that obtained for the ideal emulsion by forming the quotient of the total number of grains over the standard deviation for the same slit-width. Alternatively, we can compare the exposure times required by the two emulsions to obtain equal figures of merit. (By letting the exposure time for the ideal emulsion be the adjustable quantity we avoid the difficulties associated with reciprocity failure in the real emulsion.)

Accordingly, a figure of merit was obtained from measures made on an intensitometer record of a Kodak 103aO emulson exposed step-wise and developed for five minutes in D-19 at 68° F. It was found that the figure of merit varied somewhat with density, but was always approximately 30 for densities such as are typical of good spectrograms. The analyzing slit width was 0.01 mm., and the slit length (0.35 mm.) was equal to the height of the spectrum considered later.

To obtain a comparable figure of merit for the ideal emulsion it is

necessary to compute the number of photons involved in the exposure. An exact computation would require a knowledge of the wave-length distribution of energy in the light received from the star, but a simpler, approximate method will be used, based on the not unreasonable assumption that the number of photons per angstrom received from a star of zero colour index is approximately constant in the wave-length range λλ4000-6000. This wave-length region is chosen to include both the visual and photographic rays because, on the one hand, the unit of light flux (lumen) is defined for λ5550, whereas, on the other hand, we wish to apply our criterion of efficiency to the most sensitive emulsions available, and these have a maximum sensitivity near 4200 A. As the source is to be a star we can make use of the fact that a star of visual magnitude +0.8 is equivalent to a one candle-power source at a distance of 1 km.,[2] or, more conveniently, a star of magnitude +5.8 is equivalent to a 1 c.p. source at 10 km. distance. Thus the amount of light (L) in lumens collected by, say, a 72-inch telescope (radius = 91.5 cm.) from a 5.8 magnitude star will be equal to the solid angle in steradians subtended by the 72-inch disk at a point 10 km. distant. We get

$$L = \frac{\pi(91.5)^2}{10^{12}} = 2.635 \times 10^{-8} \text{ lumens.}$$

In order to convert this flux into number of photons per second we make use of the mechanical equivalent of light, which, for the wave-length of maximum visual luminosity (λ5550),[3] is 650 lumens per watt.[4] The energy (E), in joules, of a photon of wave-length λ is given by

$$E = hc/\lambda$$

where h = Planck's constant = 6.62×10^{-34} joule sec.
c = velocity of light = 3.00×10^{10} cm./sec.

Setting $\lambda = 5.55 \times 10^{-5}$ cm. we get

$$E = 3.58 \times 10^{-19} \text{ joules per photon.}$$

Therefore a flux of 2.635×10^{-8} lumens represents

$$\frac{2.635 \times 10^{-8}}{650 \times 3.58 \times 10^{-19}} = 1.13 \times 10^{8} \text{ photons/sec.}$$

Now this is the total effective luminous flux computed on the basis of the mechanical equivalent of light at the wave-length of maximum luminosity for the average human eye. The luminosity function for the eye, according to Zworykin,[5] is a bell-shaped curve having an equivalent

width of 1070 A.* Therefore the computed number of photons, for the purpose of obtaining the flux per angstrom, can be regarded as distributed uniformly over a wave-length interval of 1070 A. Using this figure we get, for the numerical flux per angstrom,

$$1.13 \times 10^8/1070 = 1.06 \times 10^5 \text{ photons/A./sec.}$$

If this flux of starlight is passed through a spectrograph† having a dispersion of D A./mm. and the resulting spectrogram is analyzed with a slit of width w mm., then the photon flux (n) per slit width is

$$n = 1.06 \times 10^5 \times Dw \text{ photons/sec.}$$

Applying this formula to the medium-focus, one-prism spectrograph (IM) of the Dominion Astrophysical Observatory which has a mean dispersion of 30 A./mm., and using the same slit-width as before (0.01 mm.), we get, for an exposure of 0.028 second:

$$n = 1.06 \times 10^5 \times 30 \times .01 \times .028 = 884 \text{ photons,}$$

and for the figure of merit:

$$FM = n / \sqrt{n} \doteq 30.$$

It is seen that the figure of merit for the ideal emulsion (neglecting telescope and spectrograph losses) is roughly equal to that obtained in practice. We can compare this computed exposure time of 0.028 sec. with the actual exposure time required by the 72-inch telescope and IM spectrograph to obtain a well-exposed spectrogram of a star of magnitude 5.8. This latter time, under better than average atmospheric conditions, is about 240 seconds, using a 103aO emulsion. Therefore we may say that the effective quantum efficiency (the ratio of the ideal exposure to the actual) of this spectrograph is $0.028/240 = 0.000116$, or, in terms of stellar brightness, +10 magnitudes.

A part of this factor of 10 magnitudes can be attributed to the loss of light in the telescope and spectrograph, particularly at the entrance slit of the latter. Allowing three magnitudes for these losses we arrive finally at an estimate of the effective quantum efficiency for spectroscopy of the Kodak 103aO emulsion of +7 magnitudes.

This very low efficiency is certainly not fundamental to the photographic process, and therefore it can be expected that more efficient

*Obtained from Zworykin's table by numerical integration.

†Later we make allowance for the fact that the spectrograph will not pass all of this light.

emulsions may be developed. In the meantime, however, it appears worthwhile to investigate all possible alternatives[6] to photography for the recording of optical images. Of the other methods, those involving the photoelectric process show the greatest promise at the present time, for, unlike radiation detectors which depend on thermodynamic processes, the photoelectric device is theoretically capable of approaching unit efficiency. Indeed, quantum efficiencies of more than 20 per cent. have already been realized for certain photoelectric surfaces,[7] and 33 per cent. is reported by V. I. Kressovsky.[8]

The photoelectric devices that have been developed for the detection of images are known as image tubes.[9] These tubes differ from the more familiar photoelectric cells by their possession of image-forming properties—that is, they direct the electrons ejected from points on the photoemissive surface, or cathode, to corresponding points on the collection electrode, or anode. Thus the pattern of electron impacts on the anode is a reproduction of the optical image on the cathode. This reconstituted image is made visible by constructing the anode of fluorescent material. The brightness of the fluorescent image increases with the anode voltage applied to the tube, and can be made to exceed that of the primary optical image.[10] An image tube used in this way is called an "intensifier." The spectral character of the fluorescent image depends only on the phosphor, and it can be chosen to meet given requirements. An image tube having a cathode sensitive to a spectral region different from that in which the phosphor fluoresces is called a "converter".

Typical of the image converters are the infra-red viewing devices developed for military use.[11] In a sense these tubes are also intensifiers, for both the visual and photographic intensity of their output is higher than that of their input. For instance, the CV-147,[12] a British-made con-

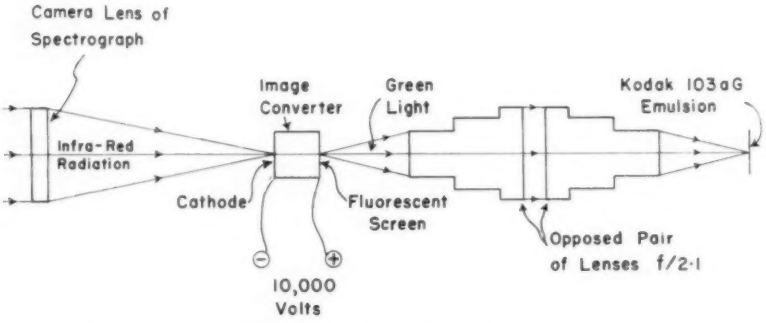

FIG. 2—Simplified diagram showing method of using image converter.

verter of very simple design, provides a means of obtaining infra-red spectra of faint objects in less time than required with Kodak IZ plates. This is achieved by photographing the green fluorescent screen of the converter by means of a fast camera and G-type plates. With an arrangement being tested on the 72-inch telescope a gain over the Z plate of 2 magnitudes was realized at λ11,000. Much greater sensitivity (nearly 5 magnitudes over the "Superfulgur" plate) has been claimed by French workers,[13] and Russian night-sky workers have also made successful use of such equipment.[14] A simplified diagram of the experimental apparatus tested at this Observatory is shown in figure 2, and a reproduction of the mercury arc spectrum obtained with it is shown in figure 3. A spectrogram made under identical conditions and exposure time using a hypersensitized Z-plate records only the bright λ10,140 line. A spectrogram of Vega taken during daylight with the image converter attached to the 72-inch telescope reveals the Paschen γ line of hydrogen and telluric water bands.

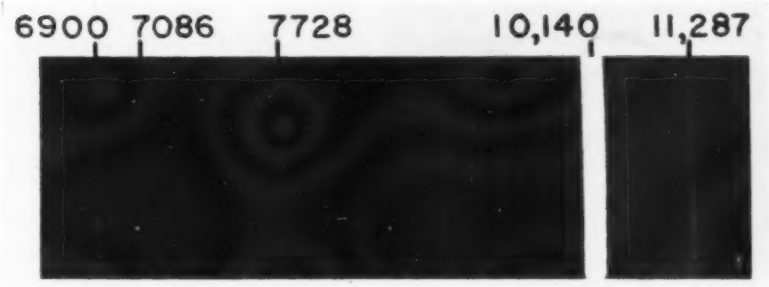

FIG. 3—Mercury arc spectrum obtained with image converter.

The conspicuous nature of these water-vapour absorptions is shown in the stellar spectra in figure 4 in the region λλ9000-9700. The upper spectrum is of α Bootis ($0^m.2$, K0) and the lower one is a wide-slit spectrum of ε Ursae Majoris ($1^m.7$, A2). In the latter the Paschen δ line of hydrogen is seen in absorption. The diagonal lines seen in both spectra are caused by the grid lines in the image-converter tube.

These achievements, preliminary though they are, make it clear that electronic methods of detecting optical images have much interest for the spectroscopist who has to contend with very low levels of illumination. Recently, however, the Kodak infra-red plates have been greatly improved and applications of the IZ(2) emulsions to the photography of stellar spectra[15] show that the new plates have superseded the simple

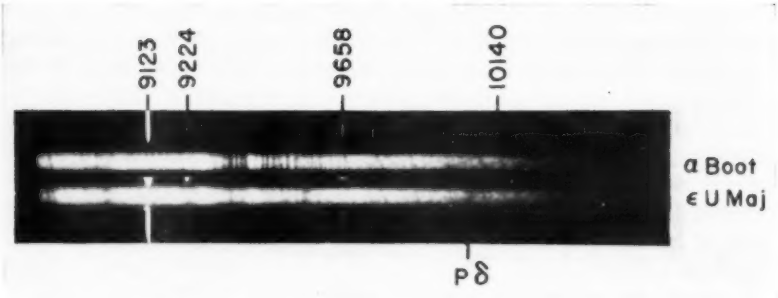

FIG. 4—Infra-red stellar spectra obtained with an image converter.

image tube used in this work. It remains for future developments to determine the ultimate relative merits of these alternative techniques.

Dominion Astrophysical Observatory,
Victoria, B.C.,
September 1954.

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SOME OBSERVATIONS OF C III EMISSION IN THE O STARS*

By Anne B. Underhill

Abstract

Some observations are presented of the C III line λ5696 in emission in the spectra of the supergiant O stars H.D. 209975 19 Cephei, H.D. 30614 α Camelopardalis and H.D. 188209. This line is also in emission in the spectra of the Of stars H.D. 188001 9 Sagittae and H.D. 192639, but it does not appear in the spectrum of the B1 supergiant H.D. 2905 κ Cassiopeiae or of the very high excitation Of object H.D. 190429N. This observation of C III emission in the spectra of the late O-type supergiants is believed to be new, and it may indicate a genetic relationship between these stars and the Of stars.

A faint rather broad emission line is present at λ5696 in the spectra of some of the O stars. The general appearance of this feature is illustrated by the spectra reproduced on the left side of figure 1. The emission at λ5696 is not present in the spectra of the B1 supergiant κ Cassiopeiae and the O4.5f star H.D. 190429N, but it is present in the spectra of the luminous O-type stars 19 Cephei, α Camelopardalis and H.D. 188209, and in the spectra of the Of stars 9 Sagittae and H.D. 192639.

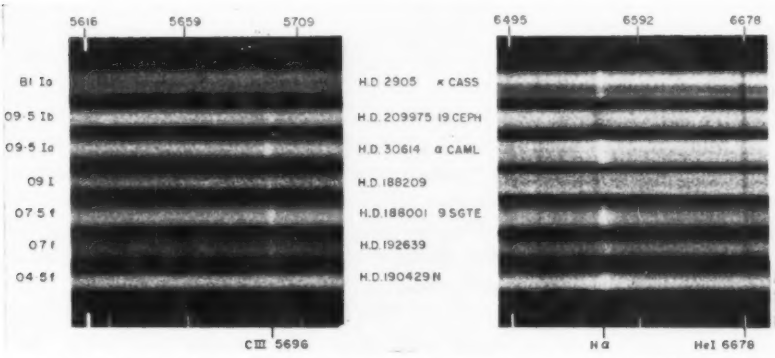

Fig. 1—Spectra of some early-type stars showing the regions λλ5615-5709 and λλ6495-6678. The emission features at λ5696 and at Hα are indicated.

This line has been observed by Beals[1, 2] at λ5695.8 in the spectra of some of the Wolf-Rayet stars, and he identified it as the $3^1P^0_1 - 3^1D_2$

*Contributions from the Dominion Astrophysical Observatory, No. 43. Published by permission of the Deputy Minister, Department of Mines and Technical Surveys, Ottawa, Canada.

transition of C III. This line has also been measured in emission at λ5695.8 in the spectrum of 9 Sagittae and at λ5696.17 in the spectrum of P Cygni by Struve and Swings,[3] who also gave the identification C III. They found this line to be present in the spectrum of H.D. 192639[4] but absent from the spectrum of H.D. 190429N.

The measured wave-length of this emission feature in the spectra of 19 Cephei, α Camelopardalis, H.D. 188209, 9 Sagittae and H.D. 192639 is given in the table. In order to correct the gross measured wave-length to zero velocity, the plate velocity for each star was estimated from the apparent wave-lengths of the He I absorption lines λ5876 and λ6678. The mean wave-length from all the plates (weighted equally) is 5695.86 A. Since the C III wave-length given in the *Revised Multiplet Table*[5] is 5696.0 A., and since the measured wave-length agrees with the measurements of Beals and of Struve and Swings, it is likely that this emission feature is due to C III. No other C III lines are observed in emission in the spectra of these stars.

THE MEASURED WAVE-LENGTH OF THE EMISSION FEATURE

Object	No. Plates	Mean λ	Object	No. Plates	Mean λ
H.D. 209975 19 Ceph	1	5695.78	H.D. 188001 9 Sgte	2	5695.72
H.D. 30614 α Caml	1	5696.12	H.D. 192639	2	5696.03
H.D. 188209	2	5695.75			

Although it has been known for some time that Hα appears in emission in the spectra of some early-type supergiants, it has not, to our knowledge, been known that the C III line λ5696 appears in emission in the late O-type supergiants. Since this line also appears in emission in some of the Of stars and in Wolf-Rayet stars of the carbon sequence, it seems probable that these stars have some similar properties.

The spectral region near Hα is shown on the right side of figure 1. There appears to be no direct correlation between the intensity of the Hα and the C III emission, for although the emission at Hα is strong in the spectra of κ Cassiopeiae, B1Ia, and H.D. 190429N, O4.5f, emission at λ5696 is absent, while in the spectra of 19 Cephei, O9.5Ib, and H.D. 188209, O9I, emission at Hα is absent or very weak, yet there is some emission at λ5696. Emission is strong at Hα and moderately strong at λ5696 in the spectra of α Camelopardalis, O9.5Ia, 9 Sagittae, O7.5f, and H.D. 192639, O7f. The spectral types by Morgan and his associates[6, 7] have been used for the early-type stars which show no emission lines in

the blue part of the spectrum range, in order to indicate the probable high luminosity of these objects. The spectral types by R. M. Petrie[8] are used for the Of stars. Petrie finds an absolute magnitude —5.6 for 9 Sagittae, —3.6 for H.D. 192639, and —6.0 for H.D. 190429N. Miss Roman[9] has presented evidence from a study of some of the O and B stars in Cygnus that the Of stars are very luminous.

The absence of the C III line λ5696 from the spectra of κ Cassiopeiae and H.D. 190429N may be in part an ionization effect. The second and third ionization potentials of carbon are 24.376 volts and 47.864 volts. In the atmosphere of the B1 star, κ Cassiopeiae, the second ionization of carbon may not be sufficiently advanced for the supply of C^{++} atoms to be enough to give an observable line, while in the atmosphere of H.D. 190429N, where the ionization temperature is very high, the third ionization of carbon may be so far advanced that the supply of C^{++} atoms is again insufficient to give an observable line.

Until the mechanism causing λ5696 to appear in emission is identified, nothing can be said about how this mechanism might vary with spectral type. The upper level of λ5696 is 3^1D_2 and it cannot be reached by a dipole transition from the 2^1S_2 ground state of the C^{++} atom. Thus any process for specifically filling the 3^1D_2 level by exciting atoms from the ground state of C^{++} must be a two-stage process.

Dominion Astrophysical Observatory,
Victoria, B.C.,
November 1954.

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NOTES FROM OBSERVATORIES

David Dunlap Observatory

Observations

The twelve months ending in the summer of 1954 saw the best average sky conditions encountered here for some years. Good progress was made on a new radial-velocity programme relating to distant blue supergiant stars and on a new programme to measure luminosities of yellow and red stars. In the field of direct photometry Dr. Helen Hogg obtained many photographs of globular clusters particularly with the 19-inch telescope. This telescope was used extensively also with a new recording photoelectric photometer. With this instrument precise brightness and colour measurements are being made in connection with a programme, initiated by Dr. MacRae, to study brightness and colour of a large group of stars which have recently been studied here for radial velocity and absolute luminosity. This photometric study, too extensive to be carried out entirely by the photoelectric method, has been made possible by a series of Schmidt camera photographs which have been taken for us at the Hamburg Observatory in Germany and which are being measured at the Warner and Swasey Observatory in Cleveland.

Staff

Summer assistants at the Observatory in 1954 included Messrs. Donald Morton, John Martin, Basil Kerr and Miss Olga Mracek of Toronto and Mr. Ghislain Roy of L'Ecole de Marine at Rimouski.

Miss Barbara Creeper, Secretary-Librarian, was married this year to Mr. Vic Gaizauskas, a former assistant at the Observatory. Mrs. Gaizauskas has left her position here to accompany her husband to Ottawa where he has accepted a position at the Dominion Observatory. Her position here is being taken by Miss Cecily Mader who has come recently to Toronto from Halifax.

J.F.H.

METEOR NEWS

By Peter M. Millman, *National Research Council, Ottawa*

Visual Observations of Perseid Meteors, 1954

As in past years the Montreal Centre of the Society carried out observations of the Perseid meteors during the 1954 return of this shower. Conditions for photographic and visual observations were not favourable as full moon occurred on August 14, very near shower maximum.

The Montreal group was led by Miss I. Williamson and observed on the night of Aug. 13/14 from Hemmingford, Que., latitude 45° 03′ N., longitude 73° 35′ W. Those who took part are listed below:

E. E. Bridgen, Miss Anna M. Burditt, Brian Cockhill, F. DeKinder, D. E. Douglas, Donald Frappier, Charles Good, Miss Rosemary Jamieson, Bernard Jones, Ian Miller, Brahm Muhlstock, A. R. MacLennan, Tom Noseworthy, Miss Cynthia Scott, Paul Scott, David Smith, Robert Venor, Miss I. Williamson, Miss L. Wilson, Miss Arden Taylor, David Zackon, Mrs. D. Zorgo.

Twelve observers were on duty at one time. The weather was generally clear except for patchy clouds in the south-west at 2100 hrs., changing to broken clouds moving past the zenith at 2200 hrs. The numbers of meteors seen in each twenty-minute interval are listed in the second and third columns of Table I. The hourly rates reduced to six observers will be found in columns 4 and 5 of Table I. The peak rates of around 15 Perseids per hour are only one third to one quarter of those recorded on a dark moonless night near Perseid maximum. The magnitude distribution of the Montreal observations is given in Table II, the bright mean magnitude being a result of the moonlight.

Observations of the Perseid meteors were also made by Glenn Hardie in British Columbia, assisted by Gordon Hardie and William Morrison. Their location was Westview, latitude 49° 50′ N., longitude 124° 32′ W. On Aug. 12/13 considerable stratus cloud was present and from 2245 to 0107 hrs. P.S.T. 16 meteors were observed, all but three being Perseids. On Aug. 13/14 with clouds present 4 Perseids were observed, 2251 – 0000 hrs. On Aug. 20/21 it was clear up to midnight and 24 meteors were observed, 2207 – 0007 hrs. The magnitude distribution of the meteors observed by this group has been listed in Table II.

It may be a good place here to point out that conditions for Perseid observations will be much more favourable in 1955. Thanks are due to Miss J. Stewart for assistance in preparing the accompanying tables.

TABLE I

NUMBERS OF METEORS OBSERVED AT HEMMINGFORD, QUE.

1954 Aug. 13/14, EST.	Meteors Observed		Hourly Rates (six observers)	
	P	N	P	N
2050–2110	0	1		
–2130	1	1	2	2
–2150	1	0	2	2
2150–2210	0	1	1	1
–2230	0	0	0	1
–2250	0	0	2	0
2250–2310	2	0	2	0
–2330	1	0	3	0
–2350	1	0	4	0
2350–0010	3	0	6	2
–0030	4	2	13	2
–0050	10	1	14	4
0050–0110	4	2	15	5
–0130	5	3	10	5
–0150	4	1	10	3
0150–0210	4	0	11	2
–0230	6	1	15	1
–0250	9	0	17	2
0250–0310	7	1		
Totals	62	14		

TABLE II

MAGNITUDE DISTRIBUTIONS

Station	–2	–1	0	1	2	3	4	5	6	Totals	Mean Mag.
Hemmingford	2		5	17	28	18	6			76	1.93
Westview		2	6	7	10	8	9	1	1	44	2.18

NOTES AND QUERIES

Super-systems of Galaxies

We have often heard of the Local Group of galaxies, which contains more than a dozen members, our own galaxy, the Andromeda Nebula and the Magellanic Clouds being among them. It is now believed that this is only a minor element in a local super-galaxy which Vaucouleurs estimates extends some 20 million light-years in the direction of the north galactic pole where the majority of the members appear to be. Vaucouleurs has made a complete analysis of the distribution of the nebulae in the Shapley-Ames catalogue to the 13th limiting magnitude. This analysis gives strong evidence for the existence of a highly flattened super-system, of a circular contour 20 million light-years in diameter and 3 million light-years thick. Our galaxy is placed near the southern edge of the disk, 7 million light-years from its centre, which is seen in the direction of Coma from our viewpoint. This super-galaxy contains about two thirds of all galaxies brighter than 12th magnitude. Vaucouleurs claims there is another nearby super-galaxy in the southern constellations Cetus, Fornax, Eridanus, Horologium and Dorado, seen edge on. It extends over $50° \times 10°$, has a diameter of 8 million light-years and a thickness of about 1.5 million light-years, with its centre being about 10 million light-years from us.

B.R.G.

Planetary Nebulae with Spiral Structure

Among the great number of known planetary nebulae there are a few of a quite different type. Instead of a disk or ring, which is characteristic of planetary nebulae (e.g. the Ring Nebula in Lyra), these objects show arms originating in the nucleus and spiraling around it symmetrically.

A study of these interesting objects by G. A. Gurzadian (*Russ. Astr. Journal*, vol. 30, p. 487, 1953) has shown that the spiral structure is caused by a stream-like outflow of matter from two antisymmetric points of the central star. Ejection of matter is a well-known fact with novae and early O and B stars, the difference being that here the source of ejection is the whole surface of the star. A theoretical investigation has shown further that nuclei of spiral planetary nebulae must rotate very slowly, the period being of the order of a few hundred years.

Of course, with the present observing methods, such a slow motion is unmeasurable. But the fact that there are stars in a very slow rotation will have interesting cosmological significance. According to V. G. Fesenkoff the speed of rotation of a star is a measure for its evolutionary stage. If such a relation could be established, it would give a clue to the question of the nature of planetary nebulae and their place among different types of stars.

G.A.B.

A Double-tailed Comet

In the course of the National Geographic Society-Palomar Observatory Sky Survey with the 48-inch Schmidt telescope, the comet 1953g was discovered in October 1953. The comet passed perihelion on July 9, 1954, and was easily observed in small telescopes during June. On June 30, 1954, the magnitude was estimated as 6.

The interesting thing about this comet was the faint, second tail, situated at about 105 degrees in a clockwise direction from the principal tail. The lengths of the projections of the two tails on the plane of the sky were about one and one half degrees and one half degree for the brighter and for the fainter tails respectively. Assuming that the longer and brighter of the two tails extended away from the sun, computations indicated that the fainter tail, even in the extreme, limiting case where it would be pointing almost directly away from the earth, would be more than 45 degrees from the brighter one. If the faint tail were pointing almost toward the earth, it would be nearly 135 degrees from the brighter tail. It is remarkable that the faint, distinct secondary tail was inclined at least 45 degrees to the line joining the comet and the sun.

B.R.G.

Reports on Radio Astronomy

Three pamphlets have been received, reporting on different aspects of radio astronomy. *Occasional Notes*, vol. 3, no. 16, 1954, published by the Royal Astronomical Society, contains accounts of a number of important phases of work in radio astronomy, written by members of the staff of the Experimental Station at Jodrell Bank in Cheshire. The introductory chapters deal with the principles of radio telescopes and techniques. Just as with optical telescopes, increasing the aperture of the instrument increases the resolving power, although the radio telescope cannot compete with the optical telescope in this regard; a radio telescope with the resolving power of the eye would require an aperture of a mile. Techniques are discussed in two main sections: the first is concerned

with the reception of radio signals from the sun and more distant sources, the second with the reception of radio-echoes, the pulses being transmitted from equipment on earth, reflected from near-by objects, and received again with sensitive equipment. This latter technique is used in the study of meteors, aurorae and the moon. Observations of meteors and aurorae by visual means are handicapped by the need of clear skies and no moon. Radio-echo techniques remove both of these restrictions. By studying the changes in the intensity of the echoes received from the moon it may be possible to learn more about the ionosphere of the earth.

Chapters also include discussions of radio waves from the sun, the galaxy, and interstellar hydrogen, the identification of radio sources with known objects (the identifications of the two strongest sources, in Cassiopeia and Cygnus, still remain a mystery) and the scintillation of radio stars.

The final chapter discusses radio waves of extra-galactic origin. The workers at Jodrell Bank, using equipment operating at a frequency of 158.5 mc./sec., have successfully detected radiation from the Andromeda Nebula. The intensity of the radiation, integrated over the source, gives a value which agrees very well with that expected from our galaxy if observed at the distance of M 31. This is further evidence of the similarity between the two galaxies. Six other late-type spirals have been detected, including M 81 and M 101 in Ursa Major and M 51 in Canes Venatici. A scale of apparent radio magnitudes is defined. The radio and photographic magnitudes agree remarkably well for five of the seven spirals, and suggestions are made to account for the discrepancies in the other two, M 31 and NGC 891. The difference in the case of M 31 may be caused by its particularly large size, and in the case of NGC 891 may be due to the dark absorbing line in the central plane of this spiral which is seen edge-on. So far no elliptical nebulae have been detected at radio frequencies.

The International Scientific Radio Union (U.R.S.I.) has published *Special Reports* nos. 3, 4, and 5. (Reports 4 and 5 are contained in the same booklet). The titles are "Discrete Sources of Extra-terrestrial Radio Noise", "The Distribution of Radio Brightness on the Solar Disk" and "Interstellar Hydrogen". These reports can be obtained from the General Secretariat of U.R.S.I., 42 Rue des Minimes, Brussels, Belgium.

The U.R.S.I. reports discuss their subjects in greater detail than is possible in the *Occasional Notes*. The Tenth General Assembly of U.R.S.I. was held in Sydney, Australia, in 1952. At this time sub-committees were formed to prepare reports on the subjects discussed at the meetings.

Footnotes have been added so that the material of the reports has been brought up to the date of publication.

Radio astronomy is a relatively new development. Only one book has yet been published on the subject, "Radio Astronomy" by Lovell and Clegg (see review in this JOURNAL, vol. 47, p. 123, 1953). These booklets, including references to published papers, and summarizing the work in the different fields of radio astronomy, are thus particularly welcome.

R.J.N.

HENRI MINEUR, 1849–1954

French astronomy has suffered a great loss by the death of Henri Mineur, the director of Institute d'Astrophysique in Paris. He died on May 7, 1954 at the age of 55.

Mineur, a brilliant mathematician, had been interested in astronomy from youth. As a professional astronomer he became connected with the Observatory of Paris in 1925 and later, in 1936, he became the head of the newly-created Astrophysical Institute.

His main astronomical interest covered the field of relativity, the evolution of double stars and galactic rotation.

From a study of Cepheids and RR Lyrae-type variables he was able to determine the coefficient of interstellar absorption. Also he recognized the fact that these two types of variables form two distinct families of stars—now known as population I and II. He demonstrated that the period-luminosity law for Classical Cepheids had a zero point error amounting to about one magnitude. Later and by a different method, Baade obtained the same value for the zero-point correction.

During the last war Mineur was an active member of the French underground movement for which he was rewarded "la Medaille de la Résistance" by the French Government.

G.A.B.

VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Recorder*

The annual meeting of the A.A.V.S.O. was held in two parts this year. Our charter of incorporation in the Commonwealth of Massachusetts requires that our business meeting be held within the state. Therefore, our annual meeting was held at the A.A.V.S.O. Headquarters in Cambridge on October 7, 1954, for transaction of business, and a session for reports, papers and social affairs was held at Brown University, Providence, Rhode Island on October 8 and 9—our gracious hosts: Professor and Mrs. Charles H. Smiley.

The officers for the year 1954–55 are:

President:	Cyrus F. Fernald	Council Members:	Ralph N. Buckstaff
1st Vice President:	Margaret Harwood		Dorrit Hoffleit
2nd Vice President:	Richard W. Hamilton		Walter P. Reeves
Secretary:	Clinton B. Ford		Francis H. Reynolds
Treasurer:	Percy W. Witherell		John J. Ruiz
Recorder:	Margaret W. Mayall		Charles H. Smiley
			Domingo Taboada

Our membership ranks continue to grow, and we elected two sustaining members and 25 annual members. One more sustaining member and six annual members were also elected by a mail vote of the Council a few weeks after the meeting. The new members are:

Joseph Andrews, *Pennsylvania*; Mrs. Annie Laurie Buckstaff, *Wisconsin*; James H. Carlisle III, *South Carolina*; Gary Chapman, *Arizona*; William G. Cleaver, *Connecticut*; Cowasjee M. Cowasjee, *Pakistan*; Christine Culp, *Michigan*; Charles H. Davis, *Indiana*; Arthur Dalton, *Canada*; Robert S. Evans, *Canada*; Robert Fellenz, *Wisconsin*; John E. Gaustad, *Minnesota*; William H. Glenn, *New York*; Leon E. Gold, *New York*; George Hein, *New York*; Mary R. Hunt, *Ohio*; Maxwell Kimball, *New Jersey*; Franklin C. Loehde, *Canada*; John C. Lucas, *New York*; Stephen P. Maran, *New York*; Francis P. Morgan, *Canada*; Mrs. Virginia McKibben Nail, *Massachusetts*; James L. Neafus, *Indiana*; Wendell L. Perry, *New York*; James G. Peters, *Indiana*; Beaufort S. Ragland, *Virginia*; Charles L. Ricker, *New Mexico*; Florence Rosenblatt, *New York*; Keith E. Schirmer, *Oklahoma*; Steven C. Shepley, *Maryland*; Paul Skaritka, *New York*; Richard V. Warren, *Indiana*; David D. Warshaw, *New York*; R. W. Womelsdorff, *Louisiana*.

The Chairman of the Chart Committee, Richard W. Hamilton, reported a very active year, with the distribution of more than 3,000 charts to new members and

to old members who are expanding their observing programmes. Harry L. Bondy and David W. Rosebrugh reported on the revived activity of the Solar Division. Mr. Bondy is to be complimented on his fine work as Editor of the Solar Division Bulletin.

During the fiscal year 1953–1954, 136 A.A.V.S.O. observers contributed 52,028 observations. One-third of these observations were made by 36 observers in 16 countries outside the United States. Reginald P. de Kock of South Africa contributed the greatest number of observations this year: 6,549. Second place was taken by Edward Oravec of New York with 4,112; next was Cyrus Fernald of Maine with 3,571; in fourth place was Charles Aronowitz, New York, with 3,256; fifth was Demetrius Elias, Greece, with 2,599; and in sixth place was Curtis Anderson, Minnesota, with 2,418.

In addition to the observation of stars on our regular programme, Gunnar Darsenius of Sweden had a total of 6½ hours of observation on the flare star Krüger 60B; and John J. Ruiz, New York, made 30 hours of photoelectric photometer tracings of the short-period variable u Herculis.

The Thirteenth A.A.V.S.O. Mérit Award was presented to Mr. Roy A. Seely, "In recognition of his faithful devotion to the interests of the Association for over thirty years; of his loyal services as President and Secretary; and especially of his untiring efforts in producing new variable star charts." As in the past, this award was in the form of a beautiful scroll, designed and illuminated by our Patron, Mr. Fred E. Jones.

The meeting at Brown University opened with a fascinating and timely talk by Prof. Smiley on "Hurricanes." He says he does not attempt to make predictions, and yet there are people in Providence who say he told them to watch for trouble around the first of September (Hurricane Carol arrived August 31)! The other papers presented during the meeting covered a variety of subjects, as shown by the accompanying list of titles.

"Axicons—A New Optical Development," William Penhallow.
"Aviation Week Magazine Satellite Scare," John Kinsey.
"Variance Spectra of Variable Stars," Leith Holloway.
"A Simple Prominence Telescope," and "Solar Activity, January-June 1954," Harry Bondy.
"The Variable Stars of the Bar of the Large Magellanic Cloud," Virginia McKibben Nail.
"Seeing Bright Stars in Daylight," Cyrus Fernald.
"The Long Period Variables in a Field in Sagittarius," Dorrit Hoffleit.
"Another Nova in Sagittarius," Jean Dishong.
"An Apodizing Screen," David Rosebrugh.
"Observations by the Yard, The Old and the New," John Ruiz.
"Complex Light Variations of DF Cygni," Margaret Harwood.
"The Eclipsed Eclipse of June 30, 1954," Clinton Ford.
"Z Andromedae," Margaret W. Mayall.
"AE Aquarii, 1954," Francis Reynolds.
"Televising an Eclipse," Roy Seely.

A feature of the meeting was the annual "Highlights of Astronomy" prepared by

Dr. Harlow Shapley. The following list is numbered as he gave them, not necessarily in order of importance.

Highlights of Astronomy, 1953–1954.

The past year has been noteworthy for interesting contributions all the way from the heart of the old astronomy (positions of stars) to the astronomical borders where the scientists of other fields (radio, engineering) contribute importantly to our knowledge of stars, galaxies, interstellar dust, and the solar system. Among the highlights I note the following, realizing of course that neither my contemporaries nor the historians ten years hence would agree on some of the items. [Items come from India, Mexico, Russia, U.S.A., with assists from Australia, England, Canada, Holland.]

1. Out of the abundance of amazing contributions in the field of radio astronomy —contributions from Holland, England, Australia, the United States, and Canada—I choose for special mention the work of John D. Kraus and H. C. Ko of the College of Engineering of Ohio State University. They have mapped much of the northern sky as it would be seen to an eye sensitive only to radiation of wave-length about four feet. The Milky Way is clearly recorded in this radiation, as well as the Virgo group of galaxies, the intensely bright galactic nucleus, and some special hot-spots in Centaurus, Cygnus, and especially Cassiopeia. To this radio eye globular star clusters remain undiscovered.

2. The dedication of the new Pulkovo Observatory, built on the site of war ruins wreckage, brings again into the national and international picture an institution that one hundred years ago was sometimes rated as the astronomical capital of the world.

3. The completion is reported of two large enterprises in the astronomy of position. At the Lick Observatory Dr. C. D. Shane, assisted by C. A. Wirtanen, has completed the first series of plates for the sky mapping programme, planned many years ago by the former director William H. Wright; and at the University of Minnesota Dr. W. J. Luyten has finished the Bruce Proper Motion Survey, adding 19,000 stars to his lists of those with appreciable motion—an investigation that has continued steadily for twenty-five years. Some decades from now the Lick Observatory series of plates will be repeated and will then provide the best material ever assembled for the study of star motions referred to distant galaxies. Evaluation of the rotation of our galaxy is one of the goals of this long-range investigation.

4. At the Mexican National Astrophysical Observatory, Tonanzintla, Puebla, Dr. Guillermo Haro, director of the Tonanzintla and Tacubaya Observatories, has discovered and measured a large number of "slow motion" flare-like stars in the nebulosities of Orion.

5. Dr. Milton Humason of Mount Wilson and Palomar Observatories has completed at least one phase of his elaborate study of the radial velocities of 580 galaxies, which, when supplemented by Dr. N. U. Mayall's measures at the Lick Observatory of the red shifts of nearly 300 galaxies, will provide the basic information on the expanding universe. Humason finds 20 galaxies with velocities in excess of 25,000 km./sec., with the greatest speeds just over 60,000 km./sec.

6. New and highly promising developments have been reported in the utilization of solar energy, including (a) the large-scale production of solar cookers in India,

(b) a practical solar cooker developed in California, which can attain a temperature under best conditions of 8,500° Fahrenheit (not much less than the temperature of the solar surface), and (c) some partially revealed developments in the Bell Telephone Laboratories and the Wright Air Development Center, which involve cells and batteries that absorb the solar radiation and make it efficiently available for heating.

7. The production of a colour-magnitude array for the globular cluster Messier 3, reaching down for the first time to stars of less candle power than that of the sun, has been accomplished by H. C. Arp and A. R. Sandage with the Hale Telescope on Palomar Mountain.

8. A new and appealing proposal is advanced by Dr. Dean McLaughlin of the University of Michigan to account for the markings on Mars. They can be reasonably explained as analogous to the Dust Bowl of the Southwest. The "trade winds" on Mars (where the absence of oceans and of long mountain ranges permits them to behave otherwise than with us) pile up, in drifts and ridges, the sand, dust, and volcanic ash, some of which, because of the lack of oxygen in the Martian atmosphere, can have a greenish tone. Thus both the canals and the life on Mars are disposed of as largely illusions produced by Martian meteorology. To provide the drift material presently or recently active volcanos are required.

9. Although only preliminary results have been reported, the wide attack on the total solar eclipse of June was noteworthy, and especially the ten-station programme of the U.S. Air Force, which distributed observers all the way from Ontario through Labrador, Greenland, Scandinavia, to Iran.

10. As a final highlight, appropriate for this and adjacent years, I should mention the extensive and very valuable programme of support for astronomical research by the U.S. National Science Foundation, as well as the not inconsiderable assistance given to pure astronomical investigations by the U.S. Air Forces, the U.S. Navy, and the National Bureau of Standards.

Nova Search Programme. During the months of September and October 1954, ten observers submitted reports. Listed for each observer is the month the observations were received, the areas observed (in italics), the number of nights the region was checked, and finally, the limiting magnitude.

BLUNCK, VICTOR H., Oct.–*8, 9, 10*: 5, 6.
DARSENIUS, GUNNAR, Sept.–*Dome*: 2, 2; *16, 17*: 4, 6; *16, 17*: 4, 5;
Oct.–*Dome*: 2, 2; *16, 17*: 1, 5; *16, 17*: 6, 6.
DIEDRICH, DELORNE, Sept.–*40*: 2, 5;
Oct.–*40*: 4, 6.
DIEDRICH, GEORGE, Sept.–*Dome*: 3, 2; *78*: 7, 6; *78*: 1, 5;
Oct.–*Dome*: 5, 2; *78*: 6, 6; *56*: 1, 6.
DIEDRICH, PAUL O. H., Sept.–*77*: 1, 4; *77*: 1, 3.
PERRY, WENDELL, Sept.–*10, 18, 36, 37, 48, 53, 54*: 1, 4½.
RICK, LOUIS, Sept.–*Dome*: 6, 2; *18, 63*: 8, 5;
Oct.–*Dome*: 7, 2; *18, 63*: 8, 5.
RAGLAND, BEAUFORT S., Oct.–*23*: 1, 5; *23*: 3, 6; *23*: 2, 6.5; *23*: 9, 7; *23*: 3, 7.5.
ROSEBRUGH, DAVID W., Sept.–*Dome*: 10, 3; *1*: 8, 4; *34*: 3, 4;
Oct.–*Dome*: 1, 2; *Dome*: 4, 3; *1, 34*: 4, 4.
WELLS, KARL A., Sept.–*Dome*: 3, 5.

Observations received during September and October 1954: In September 72 observers contributed 6247 observations, and in October 57 sent 5532—a total of 11,779 for the two months.

Observer	Sept.		Oct.		Observer	Sept.		Oct.	
	No. Var.	No. Ests.	No. Var.	No. Ests.		No. Var.	No. Ests.	No. Var.	No. Ests.
Abbey, Leonard B.	11	23	...	...	Jackiw, Roman W.	13	13	...	...
Adams, Robert M.	47	145	57	202	Johnsson, Robert G.	...	...	16	16
Ancarini, Mario	31	53	24	87	Juarez, Angel	69	69	...	...
Anderer, Joseph A.	4	4	6	16	Kanda, Sigeru	...	...	12	135
Anderson, Curtis E.	212	386	240	401	Kastin, Harold	32	38	...	...
Aronowitz, Charles	110	305	142	297	Kelley, Leo A.	3	3	5	5
Beevor, J.	2	2	...	...	Kelly, Frank	12	12	9	13
Behar, Alfred	5	17	...	...	Kimball, Maxwell	...	...	2	2
Beidler, Herbert B.	18	30	26	36	de Kock, Reginald P.	135	450	140	528
Blunck, Victor H.	...	...	5	15	Lacchini, Giovanni B.	51	167	40	113
Botham, John H.	18	43	...	...	Landingham, R. E.	5	5	...	...
Boutell, Hugh G.	7	25	6	12	Lonak, Eugene	1	6	...	...
Buckstaff, Ralph N.	23	51	17	26	Maran, Stephen P.	55	119	55	115
Bull, Harry M.	...	...	4	5	McPherson, Charles	17	24	29	29
Calothy, George	2	2	...	...	Mebius, William G.	8	10	10	13
Carpenter, Claude B.	48	48	44	44	Miller, William A.	18	19	22	23
Charles, Donald F.	8	15	38	53	Montague, Allen C.	28	40	45	68
Chiabotta, Ronald	5	5	...	...	Oravec, Edward G.	130	439	108	250
Cragg, Thomas A.	86	92	337	442	Overbeek, Michiel D.	93	444	...	...
Crouse, Linda	8	8	13	13	Parker, P. O.	42	42	32	32
Culp, Christine	2	5	...	...	Pearcy, Robert E.	6	6	7	7
Darsenius, Gunnar	25	241	40	242*	Peltier, Leslie C.	26	143	31	140
Diedrich, DeLorne	2	5	...	...	Perry, Wendell L.	17	39	7	8
Diedrich, George	2	9	3	4	Renner, C. L.	...	...	247	491
Elias, Demetrius P.	112	754	...	...	Reynolds, Francis H.	2	278	...	...
Erpenstein, Oscar M.	5	6	5	8	Rick, Louis	2	4	2	2
Fellenz, Robert	1	8	...	...	Rizzo, Patrick V.	30	46	27	45
Fernald, Cyrus F.	197	358	234	459	Rosebrugh, David W.	22	125	17	80
Flowers, Brown	2	5	...	...	Rosenfield, Donald A.	3	6	...	...
Ford, Clinton B.	178	203	117	119	Royer, Ronald	11	13	14	21
Gaustad, John E.	15	15	20	32	Schultz, Gerald W.	1	3	1	5
Gleason, William S.	...	...	5	6	Semos, Elie	5	17	...	...
Glenn, William H.	...	...	4	4	Skaritka, Paul	...	...	131	304
Goodsell, J. G.	4	4	4	4	Solomon, Leonard	1	1	...	...
Greenley, Robert M.	...	...	10	22	Sturgis, Howard E.	2	7	12	38
Hales, LaVaughn	5	7	...	...	Thurn, Vincent W.	9	17	...	...
Hartmann, Ferdinand	120	126	138	148	Venter, S. C.	113	336	...	...
Hein, George	53	195	78	255	Walsh, J. Farrell	1	1	2	2
Herring, Alika K.	3	10	2	3	Watson, Paul S.	15	19	17	28*
Hiett, Lancaster	6	14	...	...	Weitzenhoffer, Ken.	6	6	...	...
Houston, Margaret S.	...	...	3	4	Welker, Frank	7	7	...	...
Houston, Walter S.	...	...	16	28	Wyckoff, Jerome	33	54	20	32

*In addition to the regular estimates of long period and semi-regular variables, Mr. Darsenius had a total of 1 hour and 43 minutes of close watch on the flare star Krüger 60B, with negative results; and Dr. Watson had two half-hour periods of watch on AE Aquarii, during which he noted no change.

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November 1954

REVIEW OF PUBLICATIONS

A Brief Text in Astronomy by William T. Skilling and Robert S. Richardson. Pages viii plus 327; 6½ × 9½ in. New York, Henry Holt and Co. (in Canada Clarke, Irwin and Co.), 1954. Price $4.60.

There is a real place in astronomical literature for a text-book which is simple in treatment and brief, yet comprehensive in the sense that it begins at the beginning and includes the up-to-date. The authors of this *Brief Text in Astronomy* have attempted to write such a book, a book that will be suitable for a one-semester college course. If the book is all that it should be for this purpose, it must be very acceptable to another group of readers, namely those who wish to acquire, without too much difficulty, an understanding of the older basic facts of astronomy and an idea where the science is now heading. For this purpose, no less than for classroom use, the text-book style, with its breakdown into sections with marginal headings and diagrams, has many advantages over the style of popular scientific books which tend to avoid these features.

There are, it is true, a number of excellent text-books of the type referred to. Yet the subject of astronomy is expanding so rapidly that a new one is always welcome if it adds the new ideas to the old. It is not too easy to do this without increasing the bulk unduly or deleting important fundamental information. Nevertheless the authors here have made a good effort.

The text starts with a brief discussion of telescopes and other astronomical instruments, then follow sections on star study without a telescope and with a small telescope—in which there are excellent pronouncing lists of constellations and star names. Following these sections are chapters on the earth, celestial sphere, time, motions, moon, sun, planets, comets, motions of stars, kinds of stars, variable stars, groups of stars—all the "traditional" aspects of astronomy. Into these topics are integrated, in a welcome fashion, brief mention of new data or methods, such as the structure of the earth, the atmospheres of the planets, radar study of meteors, radio observations of the sun, the size of Pluto, etc.

It is in the final three chapters on stellar models, galactic structure and external systems that the reader should find most of his information on where astronomy is headed. Many of the new ideas are mentioned, for example, stellar populations, the proton-proton reaction, the new (1952)

scale of distances of the galaxies, the still newer (1954) collision of galaxies; but there are a few disappointments: no mention, for example, of galactic structure from radio astronomy observations of neutral hydrogen, no mention of the important new views on stellar associations or aggregates.

There are many fine illustrations, and at the end of the book, besides an index, there is a short list of books for additional reading and a useful glossary of technical terms. Finally there is a very fine set of monthly star maps with instructions for study printed in big legible type alongside each.

J.F.H.

Physical Meteorology by John C. Johnson. Pages xii plus 393; 6 x 9¼ in. New York, The Technological Press of the Massachusetts Institute of Technology and John Wiley and Sons, 1954. Price $7.50.

The title of this book, *Physical Meteorology*, is explained by the author to mean "those meteorological phenomena, not directly concerned with the circulation of the atmosphere, which link meteorology with other branches of science". The material thus includes such topics as atmospheric refraction, scattering and visibility, radiation studies, icing of aircraft, radar meteorology and the upper atmosphere. In this way it will interest astronomers, physicists and aeronautical engineers as well as meteorologists. The treatment of these various topics aims at being quantitative, and thus some reasonably difficult mathematical analysis is included.

Each topic is developed quite clearly from basic principles, so that a reader with adequate scientific training, approaching one of the topics for the first time, should be able to follow it through. Obviously it has not been possible to include exhaustive treatments in the available space, but at the end of each chapter there is a generous list of references and source books. This scheme should make for a good reference book, but, in one topic with which he is familiar, this reviewer was disappointed to note a serious omission, namely no reference to the important work of Garfinkel in the field of astronomical refraction.

Some of the chapters will be particularly welcomed from the point of view of the new information presented. This is especially true of the chapter on the upper atmosphere in which are given temperature, pressure, density and humidity data recently collected by rocket flights.

A set of problems at the end of each chapter will make the book all the more valuable for classroom use.

J.F.H.

The Sun edited by Gerard P. Kuiper. Pages xix plus 743; 7 × 9¾ in. Chicago, The University of Chicago Press, 1953. Price $12.50.

This is the first of four intended volumes on the subject of the solar system. It is the work of twenty-three astronomers, each chosen as an expert in some aspect of solar research. Thus, Goldberg of Michigan writes the Introduction, Strömgren of Yerkes writes on The Sun as a Star, Minnaert of Utrecht on The Photosphere, and so on. The various topics are well co-ordinated and add up to the most comprehensive account of the sun which has yet been published.

One has only to compare this work in size to earlier works on the sun and to run one's eye down the lists of references at the ends of the chapters to realize that the sun is far from neglected nowadays as an astronomical body. Thus, for example, Solar Radio Emission, the title of chapter 7, by Pawsey and Smerd of Australia, is a topic only twelve years old, yet it has already offered much new information on old problems and has provided the only evidence for great solar disturbances not heretofore suspected. Nevertheless, Goldberg ventures the opinion that "it is perhaps doubtful whether the golden age of solar physics has yet been experienced, although it may well have begun."

An exceptionally well written chapter is the long (115 pages) one entitled The Chromosphere and the Corona by van de Hulst of Leiden. This writer has the ability to present a survey of a topic in such a way as to carry the reader along almost as absorbingly as a novelist does. Starting with nineteenth century ideas of the outer layers of the sun, he traces the steady accumulation of information and progress of ideas, and integrates them into an interesting picture of the mechanism of the outer parts of the sun. He states the most serious problems still to be faced, stressing that of the maintenance of high coronal temperatures, and he believes that the answers to these must come from "the close co-ordination of observational and theoretical research."

Another chapter which deserves special mention is the one on Solar Electrodynamics by Cowling of Leeds. It has long been clear, even from the correlations that exist between sun-spot phenomena and the solar equator, that solar rotation and magnetic effects enter prominently into the observed phenomena of the solar surface. Cowling presents the various theories that attempt to link up solar rotation, electromagnetic fields, sun-spots, the sun-spot cycle and flares.

The final chapter in the book is on the subject of Empirical Problems and Equipment. Here one can learn the tricks by which the most successful observers have succeeded—for example that the best final polishing

of a coronagraph lens is accomplished by applying two or three little spots of nose oil to the surface. This chapter is well illustrated with some fine photographs, such as van Biesbroeck's superb corona pictures and Keenan's solar granulations and the ultra-violet spectrograms from V2 rockets.

Astronomers owe a debt of gratitude to Professor Kuiper of the Yerkes Observatory for editing this fine volume, and they will look forward to the appearance of the succeeding volumes in the series.

J.F.H.

MEETINGS OF THE SOCIETY

AT TORONTO

February 24, 1954—The meeting was held in the McLennan Physics Laboratory. The President, Dr. W. R. Hossack, was chairman.

The following people were elected to membership in the Society (all from Metropolitan Toronto unless otherwise stated): Edward Blain (Brantford); Philip G. Cooper; John Allen Gervais (Kitchener); Joseph Gibbs; Robert E. Harlow; R. Stanley Horton; Basil W. Ingleby; Leslie G. Japp; Rev. Bela Karolyfalvi; Norman McFee; Martin P. Macnaughton; Miss M. Kathleen Martin (St. Thomas); Miss Larisa A. Mazurenko; George E. Reesor (Pickering); Allan Walter Smith (Markham); Archibald H. Smith; Peter L. Sokolski; Dr. Fred W. Tomingas; Stephen Trakalo; Max Weinstein; Reginald S. Williams. There was one transfer, Louis Habets, from the Winnipeg Centre.

The meeting was devoted to a discussion of the plans of the Toronto Centre for observing the solar eclipse next June 30. Mr. Greenwood gave a report on the possibilities of air transportation, Mr. Publow on train transportation and Mr. Frenkel on bus transportation. Dr. Heard suggested that not only might observers photograph the eclipse, but they could try to accurately time the contacts and perhaps obtain photographs of the shadow bands, a phenomenon best seen on a white sheet spread on the ground. Shadow bands are the result of differential refraction in the earth's atmosphere and they are visible just before totality. Dr. Heard also gave a brief description of the apparatus to be used by the David Dunlap Observatory group and of the observations they hope to make. It was also pointed out that the Kapuskasing district was famed for its fishing, and Mr. Publow mentioned the possibility of arranging a tour of a pulp mill as a partial compensation should the day be cloudy.

March 9, 1954—The meeting was held at the McLennan Physics Laboratory. The chairman was Dr. W. R. Hossack, President.

The following people were elected to membership in the Society (addresses in Metropolitan Toronto unless otherwise stated): D. W. Berry; Major Alfred E. C.

Bruce; Maurice J. Field, Charles J. Flood; Albert E. Friend; George Gyulviszi, Jr. (Tillsonburg); Miss Kathleen A. Hamilton; J. Glenn Miller (Orillia); David E. Model; William C. Robb; Oscar G. Rogers; A. Lorne Ross; A. Morgan Salter; Alfred Segond (Brampton); Gordon M. Smith (Dundas); Gerald M. Thomas; Michael Tychoniuk; Maxwell C. Wallace; George F. White, Jr.

Dr. Hossack introduced the speaker, Mr. Warren Forrester, of the Canadian Geodetic Survey which has its headquarters in Ottawa. The title of Mr. Forrester's lecture was "How Astronomy Helps in Mapping Canada's North Country". A summary of this address has appeared in the JOURNAL. Mr. Forrester illustrated his lecture with beautiful coloured slides.

March 23, 1954—The meeting was held in the McLennan Physics Laboratory. The President, Dr. W. R. Hossack, was in the chair.

The following people were elected to membership in the Society (addresses in Metropolitan Toronto unless otherwise stated): John B. Acteson; William Chong; Bert Cohen; Miss Irene Farnell; Lionel B. Grainger; John F. Kern; Mrs. Joan M. Kern; Clayton V. McDuffee (Oakville); William L. Mather; Herbert L. Moyer (St. Catherines); C. Dennis Patterson; D. Bruce Robb; John S. Sara; Miss Caroline Shawyer; S. Robert Shawyer.

The Toronto Centre noted with regret the death of Mr. D. Allister Carmichael, a member of this centre for twenty years.

The meeting was turned over to Mr. Ketchum, Director of the Amateur Telescope Makers' Group. Mr. Ketchum introduced the subject of telescope building by describing the different kinds of telescopes, their history, the principles upon which they work optically, and the expense to the builder. Then followed a demonstration of grinding a mirror by Mr. Lemire and of lap pouring by Mr. Frenkel. Mr. Clark finished off the discussion by describing the methods of parabolizing a mirror.

April 6, 1954—The meeting was held at the McLennan Physics Laboratory. The chairman was Dr. W. R. Hossack, President.

The following people were elected to membership in the Society (addresses in Metropolitan Toronto unless otherwise stated): John A. Ferrier (Kapuskasing); Miss Francis M. Lean; William B. Mackenzie; Arved Vaher.

It was moved by Frederic L. Troyer, Secretary, and seconded by W. R. Sherrick that no membership dues having been received despite several attempts and promises made, the election of G. Peter Nixon at the meeting of October 27, 1953, be declared null and void, that Mr. Nixon's name be struck off the membership roll and from the Minutes of the meeting of October 27, 1953.

Dr. Heard introduced the speaker, Dr. Adriaan Blaauw, of the Yerkes Observatory. The subject of Dr. Blaauw's lecture was "Birthplaces of the Stars".

The problem of stellar evolution is one of the many problems encountered in a general study of the physics of the stars, and this problem has received much study in the past ten years. Some of the questions to be answered are what were stars like at the time of their creation? how did they evolve? what are their ages? If we assume the ages of the stars to vary, then it should be possible to arrange them in a series according to age, and hence by studying the changes in physical conditions along the sequence, form some ideas about stellar evolution. It appears that we are now getting observational facts on stars at the extreme ends of the sequence, the oldest and youngest stars.

Dr. Blaauw confined his discussion to the youngest stars, the very hot, luminous

O- and B-type stars. The age of such a star can be estimated in the following way. A star of a given mass can radiate only a certain amount of energy in its lifetime, depending partially on this mass. The masses of these very luminous O- and B-type stars are 10 to 20 times that of the sun. This would allow them to radiate their vast amounts of energy for a time of the order of 10^7 years, this value being the upper limit. This compares with an age of about 3×10^9 years for the sun and the oldest stars. Evidence points to a similar age for other stellar systems.

These very luminous stars do not show a uniform distribution throughout the galaxy, but they tend to occur in groups. The motions of the stars in these groups seem to be directed away from the central part of the group. The amount of this expanding motion can be measured, as well as the direction, and from these accurate observations an estimate can be made of the original positions of the stars in the group, and also how long the expansion must have been in progress for the stars to have moved from their original positions to their present ones. It is difficult to explain the existence of the stars before the expansion began since there is no reason why they would move into the central region. Hence it seems reasonable to assume that the beginning of the expansion of these stars coincided with their creation. From this assumption the ages of the luminous O- and B-type stars in four expanding groups have been estimated to be between 1.5×10^6 and less than 5×10^6 years in each case, values well under the upper limit of 10^7 years estimated from energy generation considerations.

These groups of stars always seem to be associated with interstellar clouds, and it is from these clouds that they are believed to have been formed. One line of speculation is that the very bright stars found embedded in a cloud complex cause the temperature in the cloud complex to rise and high pressures are created in the central regions. This would cause the outer regions to be pushed outward, or expand. In the expanding regions there appear, in photographs of such cloud complexes, dark filamentary structures which are believed to be regions of high density. It could be that these high density areas are where the luminous stars are born, sharing the expanding motion of their surroundings.

April 27, 1954—The meeting was held in the McLennan Physics Laboratory. Dr. William R. Hossack, President, was in the chair.

The following people were elected to membership in the Society (all from Toronto unless otherwise stated): John G. Bailey, Neil Carmichael, Miss Muriel E. Chapman, Ronald E. Harron, Miss Wanda Kniaz (Burlington), John Myles Leckie, Patrick O'Connor, Mrs. Edith L. Paish (Walker's Point).

The meeting was held jointly with the Toronto Field Naturalists Club. To introduce the Naturalists to astronomy, Dr. Hossack gave a brief, well-illustrated lecture on our solar system and the galaxy. He was followed by Mr. G. F. Longworth of the David Dunlap Observatory, who discussed "Bird Flights Across the Moon".

For many years possessors of binoculars and small telescopes have watched the annual migration of birds across the surface of the moon. It was not until about 1940, however, that any systematic survey was made. Louisiana State University Observatory has been the leader in this field and from their observations it has been possible to compute the flight density for example. The flight density is the number of birds passing over a front a mile long during one hour. To give some idea of the numbers involved, it was observed that on the evening of April 22, 1945 fifty-nine birds were counted in a fifteen-minute interval flying across the moon, cor-

responding to a flight density of 51,000 birds per mile per hour. One month later on May 23, at the same station, no birds were observed for hours at a time. This was not unexpected since migration was over at that point. From the flight density it is possible to obtain a better determination of bird flyways. Some other interesting points which were brought to light in these studies were that birds rarely fly above 5000 feet in migration at night, and night migrants fly singly, not in flocks. It appears that they begin taking off at twilight, the flight density increasing until about midnight, and then it gradually decreases towards dawn.

For the amateur astronomer who is interested in watching migrations, the most suitable instrument is a 2- or 3-inch telescope with a magnification of 20 to 40 power, mounted on a tripod. An erecting eyepiece is not necessary.

Since the evening was cloudy, it was not possible to have the telescopes out on the campus, so the meeting was adjourned.

October 5, 1954—The meeting was held at the David Dunlap Observatory, Richmond Hill. The President, Dr. William R. Hossack, was chairman.

After a brief business meeting, Dr. Heard welcomed the Society on behalf of the Staff. Because the sky was cloudy, it was not possible to use the telescopes, but the members were given a demonstration of the 74-inch, the 6-inch and 19-inch telescopes. The grinding machine was inspected, and there was an exhibit of instruments used in various branches of the research work carried out at this Observatory. A short lecture was given in which Dr. Heard showed slides of the David Dunlap Observatory Eclipse Expedition and Dr. Hossack gave a description of photoelectric photometry. The serving of refreshments brought the evening to a close.

BARBARA GAIZAUSKAS, *Recorder.*

AT EDMONTON

June 30, 1954—Eclipse of the sun, June 30, 1954, as observed by the Edmonton Centre.

Observers: Ian McLennan, Arthur Dalton, Marcel Dalton, Earl Milton, Mr. Montgomery, Mr. Wilson and sons, Franklin Loehde as well as a number of employees of the MacDonald Hotel.

Location: On the fourteenth-story roof of the MacDonald Hotel.

Weather Conditions: Very clear except for the occasional high cloud.

Equipment: A 6-inch reflector, 3 binoculars, 1½-inch refractor, an 8 mm. movie camera (colour) and three other cameras.

Observations: The sun rose at 4:04 a.m. Mountain Standard Time with the moon covering about 30 per cent of the sun's disk. Because of the sun being near the horizon the disk was rather elongated. A number 10 welder's glass was used to take a number of photographs through the telescope at $\frac{1}{50}$ sec. Colour movies were taken of most phases of the eclipse including sunrise. The photographs and the movies showed that about 65 per cent of the sun was eclipsed at maximum which was at 4:29 a.m. By 5:16 a.m. the eclipse was over. Lack of a short-wave radio prevented accurate timing of the last contact.

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